Power Generation and Alternative Energy Branch
US Army RDECOM CERDEC CP&ID Power Division
Aberdeen Proving Ground, MD

PGAE - TR – 11 – 05

Alternative Energy for Defense Conference

Jonathan Cristiani, US Army CERDEC CP&ID

RDER-CCA-PG

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
26 OCT 2011	**Presentation**	**26-10-2011 to 26-10-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Alternative Energy for Defense Conference	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
Jonathan Cristiani	5e. TASK NUMBER
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	8. PERFORMING ORGANIZATION REPORT NUMBER
U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER,5100 Magazine Rd.,Aberdeen Proving Ground,MD,21005-1852	**; PGAE - TR - 11 - 05**
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
U.S. ARMY COMMUNICATIONS-ELECTRONICS RESEARCH DEVELOPMENT AND ENGINEERING CENTER, 5100 Magazine Rd., Aberdeen Proving Ground, MD, 21005-1852	**RDER-CCA-PG**
	11. SPONSOR/MONITOR'S REPORT NUMBER(S) **PGAE - TR - 11 - 05**

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
An overview of the CERDEC Alternative / Renewable Energy program is provided.

15. SUBJECT TERMS
alternative energy, renewable energy

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**Same as Report (SAR)**	**35**	

Communications-Electronics Research Development and Engineering Center (CERDEC)

Alternative Energy for Defense Conference

26 Oct 2011

CERDEC
US ARMY – RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Jonathan M. Cristiani, Renewable Energy Team Leader
Army Power Division, US Army CERDEC C2D

Overview

- The Need
- Operational Energy Policy and Community
- Technology Focus Areas, Applications, and Objectives
- Emerging Tactical Alt/Renewable Energy System Requirements
- Technology Demonstrations and Transitions

THE NEED!

Fuel cost = $350,000 per year per soldier

Ref: Time Magazine “Obama Weighs the Cost of an Afghan Surge,” 25 Nov 2009.

In June 2008, 44 trucks and a total of 220,000 gallons of fuel lost to IED’s

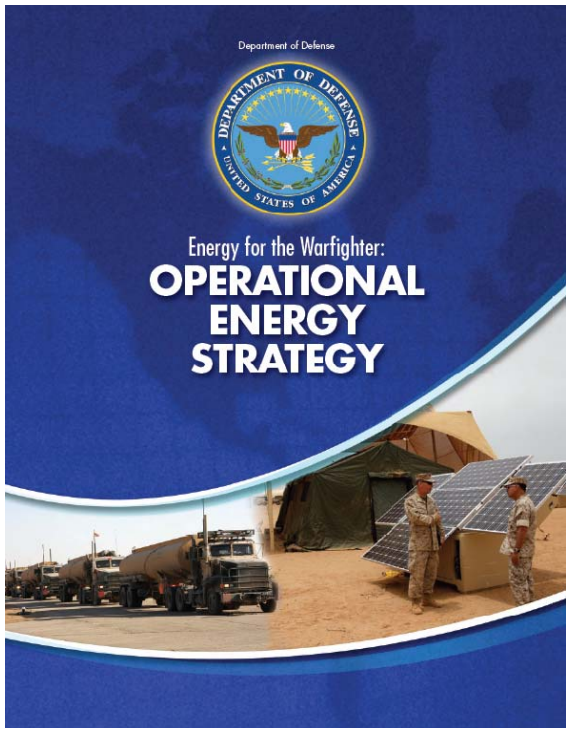
Ref: New York Times “One of the Nation's Largest Energy Users Has Ambitious Plans to Cut Back,” 28 May 2010.

Ref: http://energy.defense.gov

OPERATIONAL ENERGY (OE) POLICY

DoD Operational Energy Policy Changes

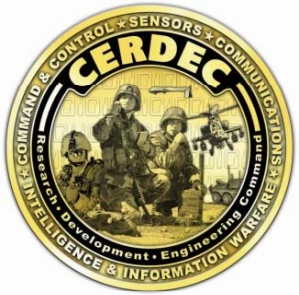
Office of the Assistant Secretary of Defense for Operational Energy Plans and Programs

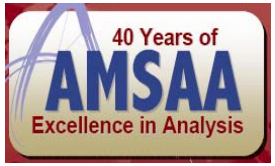


Ref: http://energy.defense.gov

- Department of Defense (DoD) Directive 5134.15 dated May 17, 2011 established the ASD(OEPP)
- The Operational Energy Strategy released by ASD(OEPP) lays foundation for defense systems energy management:
  - Document/track energy consumption of weapons systems
  - Energy key performance parameter or “e-KPP” for all programs of record
  - Use of fully-burdened cost of fuel in lifecycle cost analyses
  - Accelerate rapid acquisition of technologies that benefit operational energy in near term and accelerate transition to programs of record

DoD Operational Energy Research Dev Acq Community





TECHNOLOGY DRIVEN. **WARFIGHTER FOCUSED.**

ALTERNATIVE/RENEWABLE ENERGY (A/RE) TECHNOLOGIES, APPLICATIONS, AND OBJECTIVES

CERDEC Renewable Energy Team
Mission Summary

Enabling Technologies

- Hybrid Power
- Photovoltaic (PV), Solar Thermal, & Wind Energy Harvesting
- Waste-to-Energy (W2E) and Gas to Liquids (GTL)
- Waste heat recovery, Heat-actuated Cooling, & Co-generation

Applications

- Tactical Mobile Power
- Vehicle-mounted Auxiliary Power and Environmental Control
- Energy Security for Base Operations
- Waste abatement

Objectives

- Fuel Efficiency
- Force Protection
- Improved Mobility
- Reduced Signature
- Reduced Logistics

CERDEC Renewable Energy Team
Solar PV Module FY14 Objectives

All performance metrics reported for AM1.5 insolation and standard, temperature, and pressure (STP) ambient conditions.

	Current	Threshold	Objective	Pacing Technology
Architecture	Foldable Rigid Ruggedized Thin Glint Free* Rollable*	Foldable Flexible Ruggedized Thin Glint Free Rollable Chemically Resistant	Foldable Flexible Ruggedized Thin Glint Free Rollable Chemically Resistant	Packaging Fabrication processes Encapsulation/coating
Power density	35-40 W/kg or 50-80 W/m^2	40 W/kg or 100 W/m^2	75 W/kg or 150 W/m^2	Material selection Novel PV chemistry Encapsulation/coating
Conversion efficiencies	5 to 8 %	10%	15 %	Material selection Novel PV chemistry
Cost	$15 per Watt	$3.50 per Watt	$2.50 per Watt	Material selection Fabrication processes

CERDEC Renewable Energy Team
Wind System FY14 Objectives

	Current	Threshold	Objective	Pacing Technology
Architecture	Stationary Semi-mobile	Semi-mobile, Containerized	Containerized (>15kW) Vehicle-mounted (50W-5kW) Man-portable (50W-500W) Trailer-mounted (500W-15kW)	Novel deployment structures, collapsible blades, telescoping tower
Power Density (Nominal at 25 mph Wind Speed)	Turbine: 30-40 W/kg Turbine / Pole: 7.5 W/kg	Turbine: 40-50 W/kg Turbine / Pole: 20 W/kg	Turbine: 80 W/kg Turbine / Pole: 40 W/kg	Novel HAWT and VAWT designs, production materials/processes, system assembly, improved generators/alternators
Cost (turbine, pole, electronics, batteries)	$13.20/W	$10/W	$5/W	Low-cost turbine and deployment system production materials
Deployment / Retraction Time	>2 hours	30 minutes	15 minutes	Novel deployment structures

CERDEC Renewable Energy Team
A/RE Products, Metrics, Demos

Timetable	FY11	FY12	FY13	FY14
Portable Power (DLA / GSA / PM SWAR)		ARRA / C4ISR OTM		C4ISR OTM
Tactical Mobile Power (PM MEP / PM CP)	TSPS / AGSS	HI-Power Demos	ARRA/SBIR SBIR	REDUCE Demos
Vehicle Power (PM Tactical Vehicle / PM HTV)		TTI M915	SBIR	
Sustainment Power (PM FSS)	Net Zero Plus JCTD	ARRA		

Encampment Waste to Energy & Biofuel
Beginning TRL 4; End Goal TRL 6
METRICS: 50 gallon biofuel per ton waste, 25 gallon per day fuel synthesis

Tactical Idle Reduction Equipment
Beginning TRL 6; End Goal TRL 7
APU METRICS: 5 kW, < 600 lbs, < 0.6 gph
ECU METRICS: 1 RT at 125 F in / 90 F out
TTA Status: Signed

Portable Solar Photovoltaic (PV) Modules and Mobile Hybrid PV Power Sources
Beginning TRL 3
FY11 Goal TRL 5; FY13 Goal TRL 6
METRICS: 75 W/kg, 150 W/m2, $2.50/W

Wind Turbines and Deployment Structures
Beginning TRL 3; End Goal TRL 5
METRICS: 100 W at 20 mph, 45 lbs stowable system including MPPT and power electronics

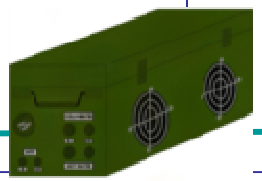
Heat Actuated Cooling and Cogeneration Systems
Beginning TRL 3/4; End Goal TRL 5
METRICS: COP 0.7, 45 kg/ton









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US Army CERDEC Applications
Portable Power

NOW

DAGR

LMR

P-Beacon

AN/PVS 14

Head Set

MBITR

Sure Fire Light

Mag Lite

PEQ-2A

Mark VII

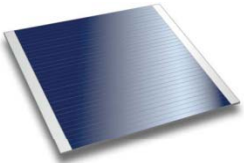
M68 CCO (Day)

HTWS (Night)

7 Battery Types
72-hrs:
70 Batteries, 16 lbs

Army Rifleman

FUTURE



AN/PVS 14

Head Set

MBITR

Sure Fire Light

Mag Lite

PEQ-2A

Mark VII

M68 CCO (Day)

HTWS (Night)

5 Battery Types
72-hr mission:
38 Batteries, 12.5 lbs

US Army CERDEC Applications
Tactical Mobile Power

"During wartime, generators become the largest single fuel consumers on the battlefield… Gen-sets in Iraq [are] overwhelmingly used for space-cooling"

Category	Peacetime OPTEMPO	Wartime OPTEMPO
Combat Vehicles	30	162
Combat Aircraft	140	307
Tactical Vehicles	44	173
Generators	26	357
Non-Tactical	51	51
Total	**291**	**1040**

Army Fuel consumption in peacetime & wartime (million gallons per year)

Ref: USD(ATL) / Defense Science Board "More Fight Less Fuel" Feb 2006.

REQUIREMENTS

Soldier-Portable Power
Overview

- Increase specific power and energy for Soldier-carried storage devices (Warfighter Outcome: 2 x power at ½ the weight);
- Reduce energy consumption by 50% by making end items more efficient and introducing power management algorithms;
- Reduce the quantity and variety of batteries (from typical 7-8) carried by the Soldier ;
- Identify locally available energy sources and Soldier power technologies;
- Provide interoperable interfaces between Soldier systems and infrastructure and vehicle-mounted energy systems.

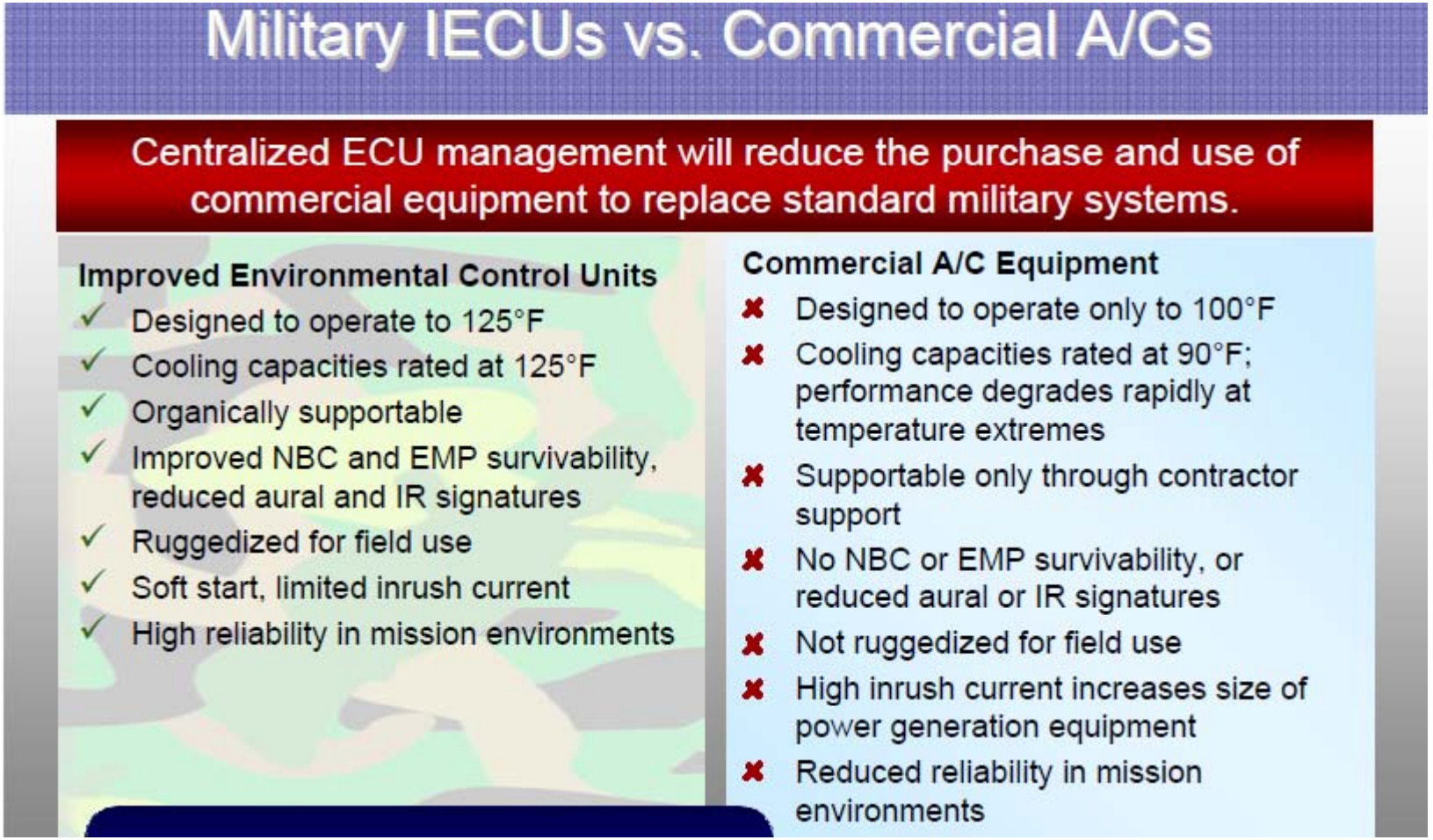
Power & Energy Strategy White Paper, Army Capabilities Integration Center – Research Development and Engineering Command – Deputy Chief of Staff, G-4, US Army , 1 April 2010

Tactical Electric Power
Overview

- Battlefield power generation and distribution provided via following **continuum**:
  - Tactical Electric Power (TEP) – Gov't owned/operated, Precise and utility grades, operation on JP-8 in all environments, 2 - 200 kW (120/240 VAC single phase, 208 VAC three phase, 50/60/400 Hz)
  - Prime Power – Gov't owned/operated, Commercial grade, 0.2 - 10 MW (2400/4160 VAC 60 Hz or 2200/3800 VAC 5 Hz)
  - Commercial Power – Not Gov't owned/operated, commercial grade, >10 MW, reliability/security risks in Iraq and Afghanistan
  - Contractor-Provided Power – Not Gov't owned/operated, commercial grade, capacities vary
- **Rules of thumb:**
  - 3 kW/person/day (bases with 5 to 3,500 population)
  - 4 kW/person/day (bases >3,500 population)

Ref: "Potential for Solar and Wind Energy Use by Expeditionary Forces" prepared by DLA DORRA per Section 333 of National Defense Authorization Act for FY 2009 - Public Law No. 110-417

- TEP systems must be designed to provide CONTINUOUS RATED POWER at these conditions:
  - 0.8 power factor (pf), lagging
  - Ambient temperatures up to 52°C (125°F) [-3% for each 10°C increment (18°F) above 52°C]
  - Altitudes up to 1,219 m (4,000 ft) [-3.5% for each 305 m increment (1,000 feet) above 305 m up to 3,048 m]
  - Operation on JP-8 as defined by MIL-DTL-83133E
- Two grades, four classes of TEP system power quality requirements: Prime and Utility Classes 2A, 2B, and 2C and as defined by MIL-STD-1332B



Ref: Mr. Jeff Taylor, PM MEP, Presentation to JOCOTAS Technical Working Group dated November 2009

Tactical Hybrid A/RE
Emerging Requirements

- Joint requirements community (with Army leadership from G4, ARCIC, and CASCOM) has drafted an initial capabilities document (ICD) for OE as of Nov 2010 and is currently working on Renewable Energy Power Sources Capabilities Development Document (REPS CDD)
- Gaps identified across power spectrum, DOTLPF can yield some operational energy reductions, but development of new materiel solutions (in the form of hybrid A/RE systems) is required

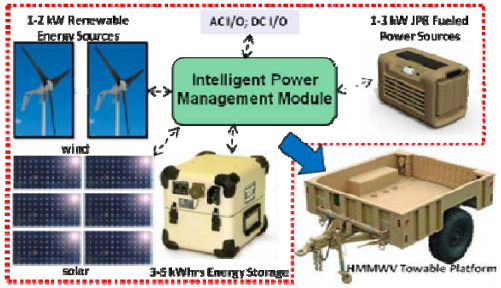
Characteristic	Threshold	Objective
Power Generation	The TSPV shall provide a *3kW* average continuous electrical power output *for 15-days* under normal operating conditions and without requiring refueling or resupply.	The TSPV shall provide a *5kW* average continuous electrical power output *indefinitely* under normal operating conditions and without requiring refueling or resupply.
Energy Storage Power Output	TSPV shall provide a *3kW* continuous electrical power output *for 12 consecutive hours* without power input from the electrical generation or energy harvesting systems and without operator intervention.	TSPV shall provide a *5kW* continuous electrical power output *for 48 consecutive hours* without power input from the electrical generation or energy harvesting systems and without operator intervention.
Trailer System	TSPV system shall use the Light Tactical Trailer-Heavy Chassis (LTT-HC). All trailer performance attributes remain in effect for the module as mounted, e.g., 4200 lb. gross weight (max), 420 lb. tongue weight and lateral stability on 40% slopes.	Threshold = Objective
Temperature	The TSPV shall be capable of sustained operation up to 95°F at 4000-ft. above sea level.	Threshold = Objective

Ref: T.E. Raney, PM MEP/CASCOM (BAE Systems, Inc.), White Paper "Tactical Solar-Photovoltaic Systems: Operational & Technical Insights", 21 Oct 2010.

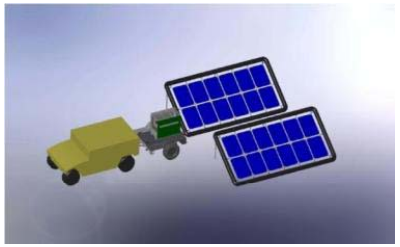
DEMONSTRATIONS AND TRANSITIONS

US Army CERDEC Hybrid A/RE *Product/Application Spectrum*

RENEWS



ASPS



TSPS

REDUCE

REPPS

AGSS

W

Applications

mW

kW

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

US Army CERDEC Hybrid A/RE *REPPS Kit*

Rucksack Enhanced Portable Power System (REPPS) Kit from Brentronics and Global Solar

- Connects to BB-2590 lithium ion rechargeable battery to allow for continuous operation of unattended ground sensors and surveillance cameras
- Flexible panels use copper indium gallium (di)selenide (CIGS) photovoltaic chemistry
- Over 100 of 725 deliverable systems have been free-issued by CERDEC under ARRA program
- Recharges BB-2590 lithium ion battery in 4 to 6 hours
- Output: 62 W at AM1.5 conditions

US Army CERDEC Hybrid A/RE *RENEWS Kit*

Reusing Existing Natural Energy Wind and Solar (RENEWS) Kit from Brentronics, Global Solar, Chinook

EACH KIT CONTAINS:

- **400 W (at 25 mph) Wind turbine & 372 W (at AM1.5) Flexible Solar Panels**
- **1.2 kWh (6 x BB-2590) "Six Pack" Battery Module**
- **250 W Inverter, Power Conditioner, & Plugs/Connectors**

- **AC/DC Output: 120 VAC / 60 Hz at 250 W & 12/24 VDC at 720 W**
- **Contained within Two x Two-man-lift Transit Cases (260 lbs total)**
- **125 systems to be delivered in late 2011 under ARRA program and free-issued to field units and training exercises**

What it Includes

Solar case
145 lbs

Wind case
115 lbs

One Kit Powers

What it Powers

Up to Two AN/PRC-117 Manpack Radios

or

Up to Five ASIP Radios

or

Any Army Standard Charger

Eliminates

What it Saves

>80 x 5590 batteries per month with 3 ASIP Radios

Weight /cost payback within 3 winter months

Remote Power for Combat Outposts (COPS) and Re-transmission Sites

US Army CERDEC Hybrid A/RE
Transportable Solar Power System

- Customer: US SOCOM
- TSPS / SPS Contractor: SunDial
- Benefits: 1 gal/hour of fuel savings
- Approx. 10 kW continuous power
- Includes:
  - 38.6 kW glass mc-Si solar PV array
  - 192 kWh AGM energy storage
  - 7 kW diesel fueled power generator
  - Deployable in 24 man hours
- Initial TRL of 6, Current TRL 9
- Objective: Obtain Safety conf. report by 31 December 2010
- 2 x TSPS deployed to Afghanistan in January 2011
- Third improved “Smart Power System” in test/safety confirmation tested by ATC deployed Sep 2011

Image courtesy of Sundial

US Army CERDEC Hybrid A/RE
Western Hemis Info Exch

- Customer: US SOUTHCOM
- WHIX Contractor: Florida International Univ. (FIU)
- Approx. 3 kW continuous power
- Includes:
  - 5 kW Ascent and Energy Tech Inc CIGS solar PV tent fly
  - 2 x 1 kW Bergey wind turbines w/ assembled foundation ARE wind towers
  - Energy storage of 36 kWhr using Li/FePO4 batt's, 4-man lift cases
  - 6 kW gas generator & 6 kW inverter
- Current TRL of 5/6
- Objective: RDECOM Consultant to SOUTHCOM and FIU
- Deployed to Dominican Republic in Apr 2011 for DR soldier training and used in dental exercise with US Army Reserves in May 2011

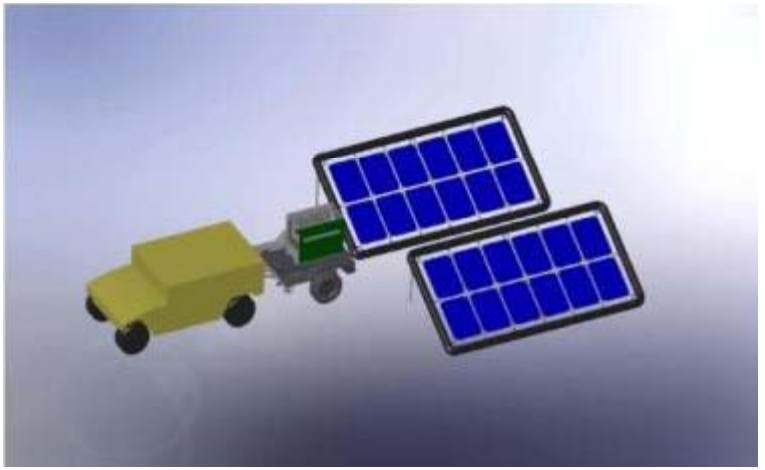
US Army CERDEC Hybrid A/RE
Automatic Gen Start System

- Customer: PM MEP / REF
- AGSS Contractor: Solar Stik
- Includes:
  - 1 kW BP Solar PV panels mounted on tripods
  - Energy storage of 10 kWh using AGM batteries, 2-man lift cases
  - 3 kW Tactical Quiet Generator modified for automatic start/stop
  - 1.8 kW inverter
- Current TRL of 6/7
- Obj: Obtain a safety confirmation by end of September 2011
- Testing and soldier demo completed by CERDEC
- 15 systems deployed in Oct 2011

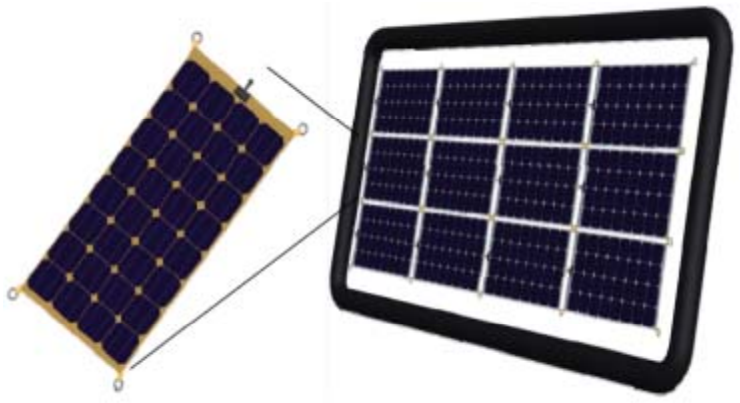
Image courtesy of SolarStik

US Army CERDEC Hybrid A/RE
Advanced Solar Power Source

- ASPS Contractors: Electricore, AeroVironment, VXE Inc
- Objective: TRL 5
  15% eff. solar PV array (10% threshold)
- Includes:
  - 2.5 kW encapsulated mc-Si solar PV array
  - Energy storage of 12 kWh Li/CoO2 (BB-2590) battery bank
  - 5 kW bidirectional inverter
  - Inflatable deployment structure
- Electricore reported 11.4% module efficiency and power dens. of >50 W/kg with exceptional bend radius
- Delivery in early FY12 to APG



Images courtesy of Electricore

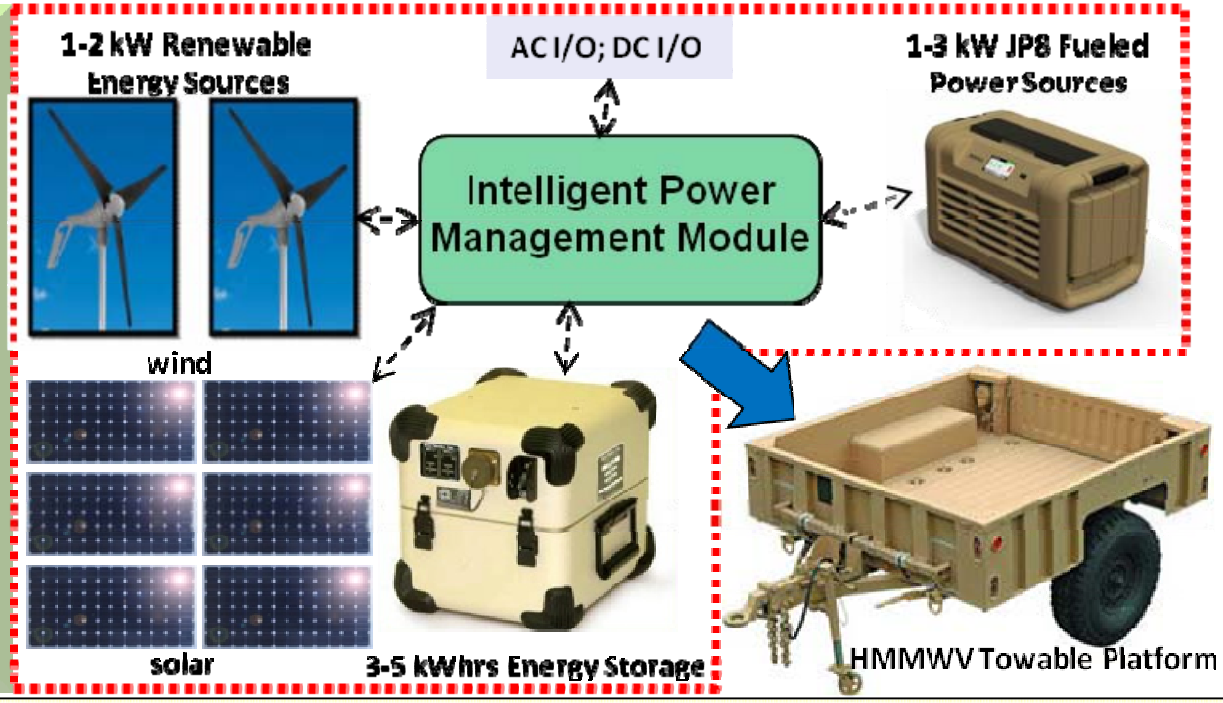


US Army CERDEC Hybrid A/RE
REDUCE Program FY12-14

Renewable Energy for Distributed Under-supplied Command Environments (REDUCE)

EACH SYSTEM CONTAINS:

- **1-2 kW Renewable Energy Devices (Photovoltaic/Wind)**
- **3-5 kWh Energy Storage Module**
- **Intelligent Power Management Module and Controls**
- **Optional 1-3 kW JP8 Fueled Power Source**
- **AC/DC Output- 115 VAC & 12/24 VDC**
- **HMMWV towable on M1101 Trailer**
- **Wt: ~200 kgs**

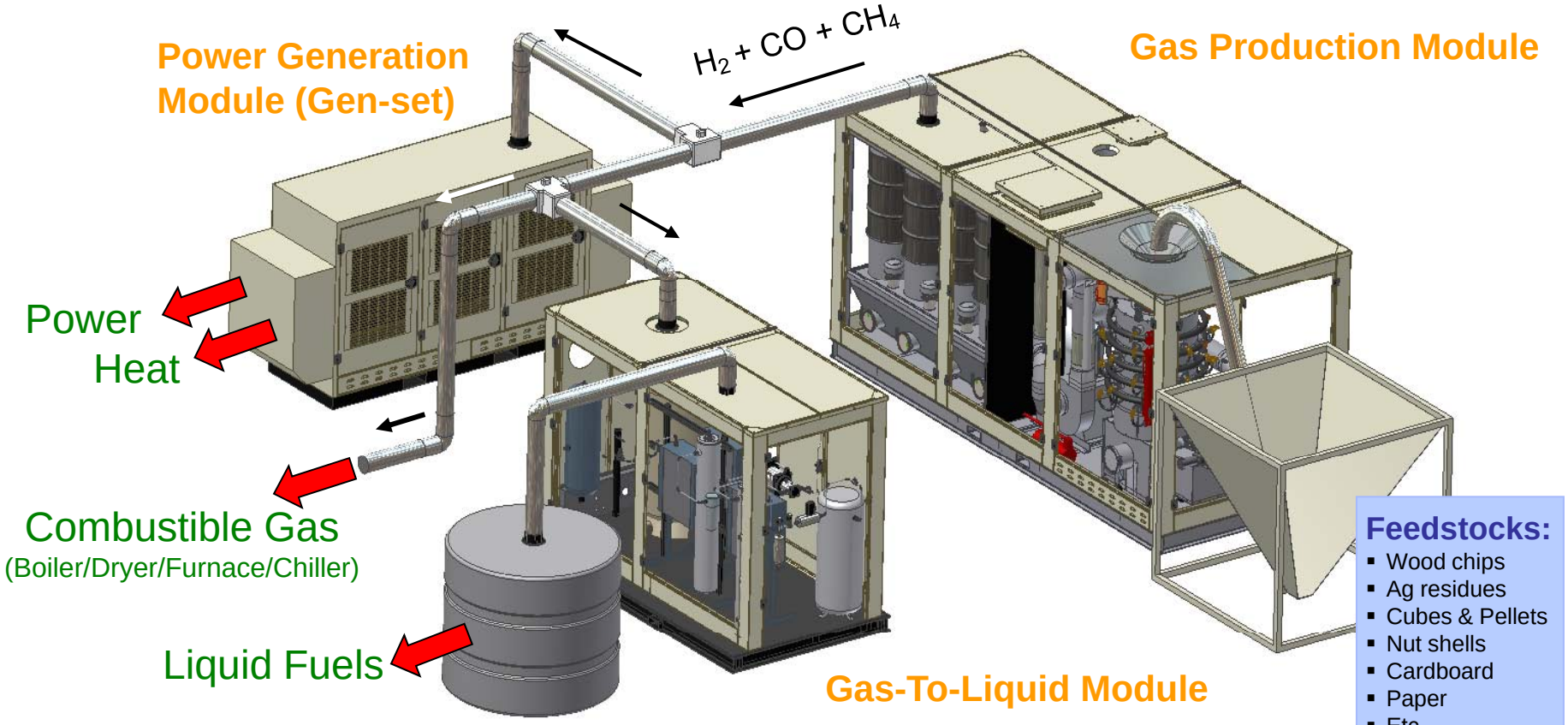


PLUG AND PLAY CAPABILITY for ease of use

Reliable Exportable Power Continuously under All Conditions

Modular System allows Component Selection based on Mission Needs

US Army CERDEC W2E/GTL
Community Power Corp Demo



50 Gallons of Syndiesel / Day
Per Ton of Biomass

Provided courtesy of Community Power Corp.

US Army CERDEC W2E/GTL
Community Power Corp Demo

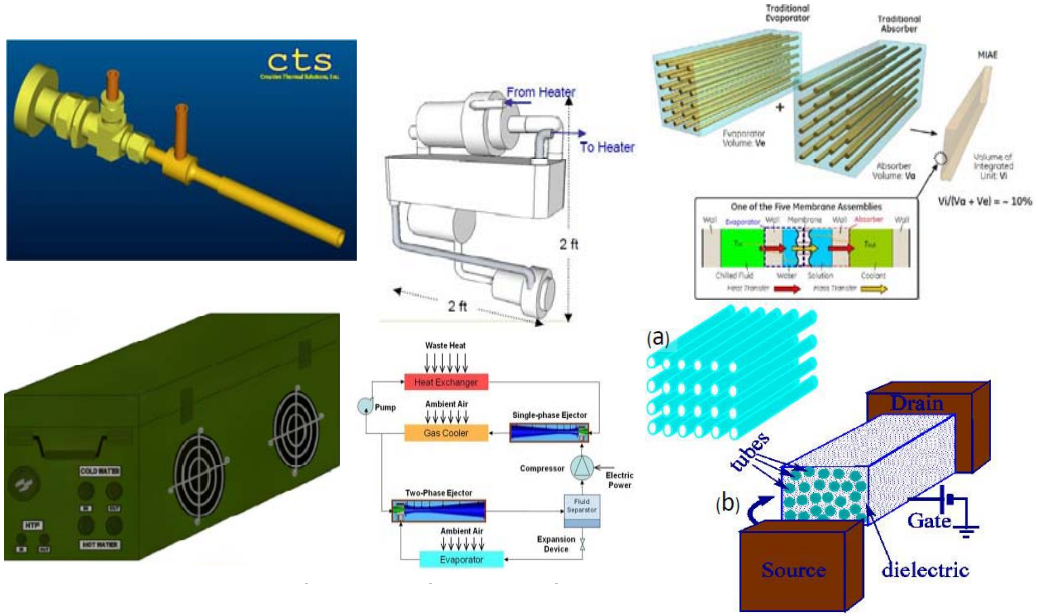
US Army CERDEC Co-Gen
ARRA for Co-gen Overview

Project Objective:

The overall objective of this program is to demonstrate the co-generation of cooling, heating, and power from waste heat sources, which may include but are not limited to diesel engine exhaust gases, engine cooling fluids, and ambient airstreams.

Approach:

Emphasis of the advanced hardware demonstrations will be on equipment mobility, compact and lightweight design, refrigerant safety (non-flammable, lower toxicity), and compatibility with military standard diesel generator systems as a source of waste heat for initial demonstration.



Benefits/Metrics:

It is well known that environmental control represents one of the most significant load requirements on the tactical battlefield today. These conditions present a unique opportunity for demonstration and transition of a smaller, lighter combined heating, cooling, and power system that provides energy efficiency and logistical benefits over the baseline stand-alone equipment. Threshold metrics at end of program: TRL 5, 45 kg/ton dry weight, COP=0.5

US Army CERDEC Co-Gen
ARRA for Co-gen Contracts

Contractor	Purpose / Status
Creative Thermal Solutions	Development of a 10.5-kWt (3-ton) diesel-engine-waste-heat-driven ejector heat pump environmental control unit (ECU) that uses carbon dioxide refrigerant.
Stone Mountain Technologies Inc	Development of a 2-kWt (0.6-ton) diesel-engine-waste-heat-driven ammonia-water absorption environmental control unit (ECU) that uses micro-scale heat exchanger technology.
GE Global Research	Development of a hydrophobic porous membrane-based integrated absorber and evaporator heat exchange device for a target 5.3-kWt (1.5-ton) lithium bromide absorption cycle.
Northwestern University	Theoretical and experimental investigation of an advanced carbon nanotube based thermoelectric generation (TEG) technology for waste heat to electricity applications.
United Technologies Research Center	Design of a 10-kWe Organic Rankine Cycle (ORC) that uses low-global-warming-potential Novec fluid to be coupled with generator sets in the 60-kWe to 200-kWe range for waste heat to electricity applications.
United Technologies Research Center	Development of a 17.6-kWt (5-ton) hybrid vapor compression cycle with two-phase ejector heat pump using carbon dioxide refrigerant.

US Army CERDEC
Tactical Idle Reduction

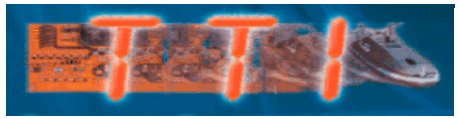
Objectives

- Transition idle reduction (TIR) equipment to Product Manager (PM) Heavy Tactical Vehicle (HTV) for M915A5 and Line Haul Replacement Tractor
- Assess power and energy requirements of current fleet of fielded HTV's: M915, M916, M917
- Adapt low-risk solutions to military requirements for power systems -- test, integrate, demonstrate, transition for procurement
- Accelerate availability of TIR equipment for procurement by 2 years from FY15 to FY13

Products

- Potential for 422 to 870 gal/yr per M915 fuel savings during wartime
- Fewer fuel convoys needed thereby increasing fleet force protection
- Significant cost savings over lifecycle through reduced prime engine use
- 5.3 kW tactical idle reduction auxiliary power unit (APU)
- Auxiliary 1 ton environmental control unit (ECU)

Team



Graphics

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Closing

- CERDEC must leverage commercial marketplace to meet near-term operational energy reduction objectives and emerging requirements
- Developers of A/RE technologies must focus on system hybridization and dual-use applications to meet interoperability / cost requirements
- Solar PV and hybrid PV systems have greatest interest from CERDEC customers in both portable and mobile markets
- DoD procurement officials seem most interested in moderate PV conversion efficiency (15%) / low cost (<$2.50/W) for large area power generation applications and high-eff (30%) / moderate cost (<$10/W) for portable power and the burgeoning smart phone market
- Wind energy systems require substantial technology development in order to be tactically viable on size/weight basis
- Energy efficiency initiatives such as W2E/GTL, Co-generation, and Tactical Idle Reduction demonstrate demand-side reduction and waste utilization, which rival the criticality of source-side hybrid A/RE